Clouds and Their Impacts in Weather Prediction and Climate Models

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NCEP-GFDL Clouds CPT

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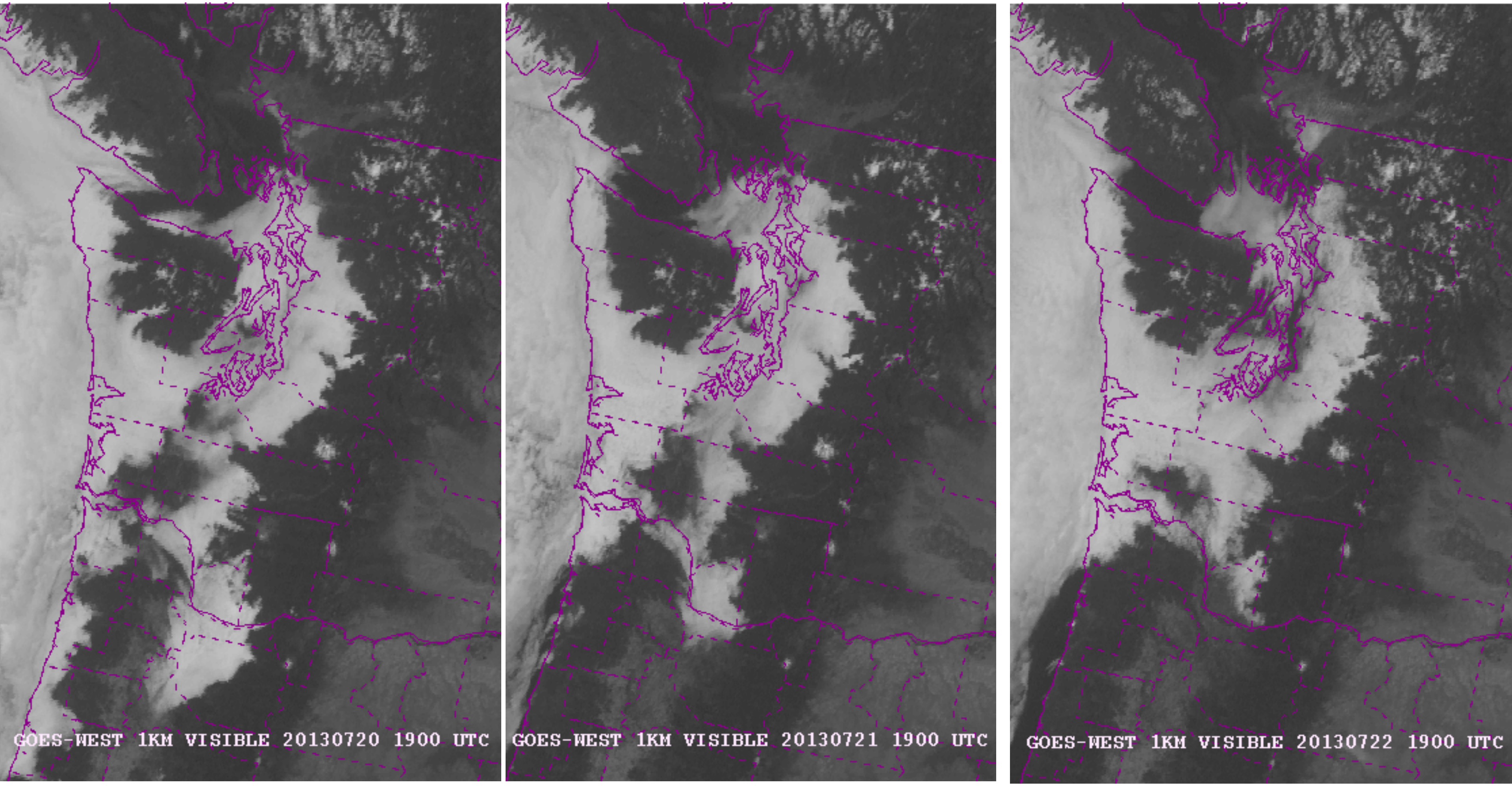
Cloud processes are important in weather and climate

- Precipitation
- Circulation
- Radiation

For radiation, predicting cloud cover and vertical extent are key.

Cloud-radiation interaction - a weather forecast challenge

Puget Sound under low Sc, noon, 20-22 Jul. 2013

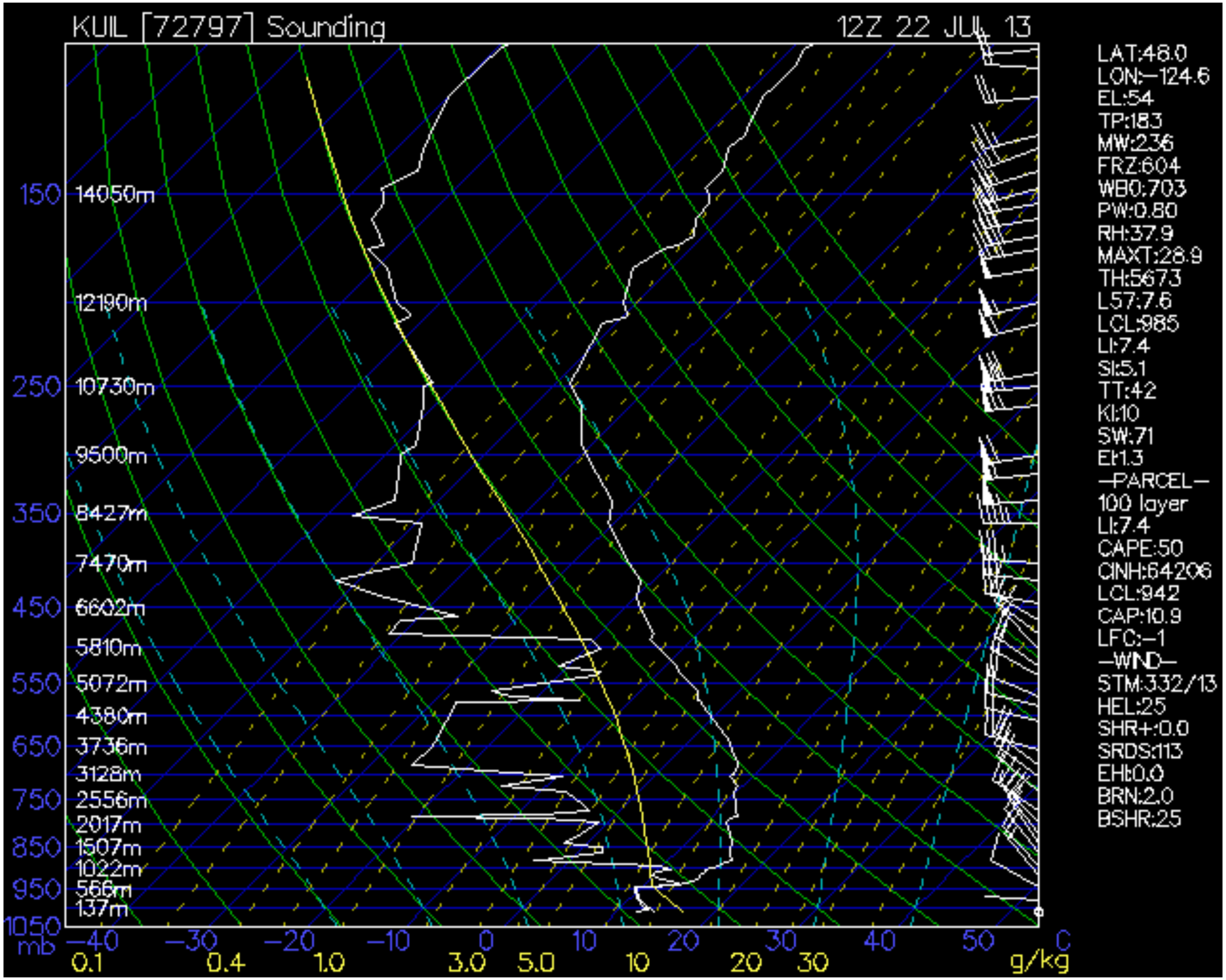


Sc breakup ~ 1pm

Sc breakup ~ 1pm

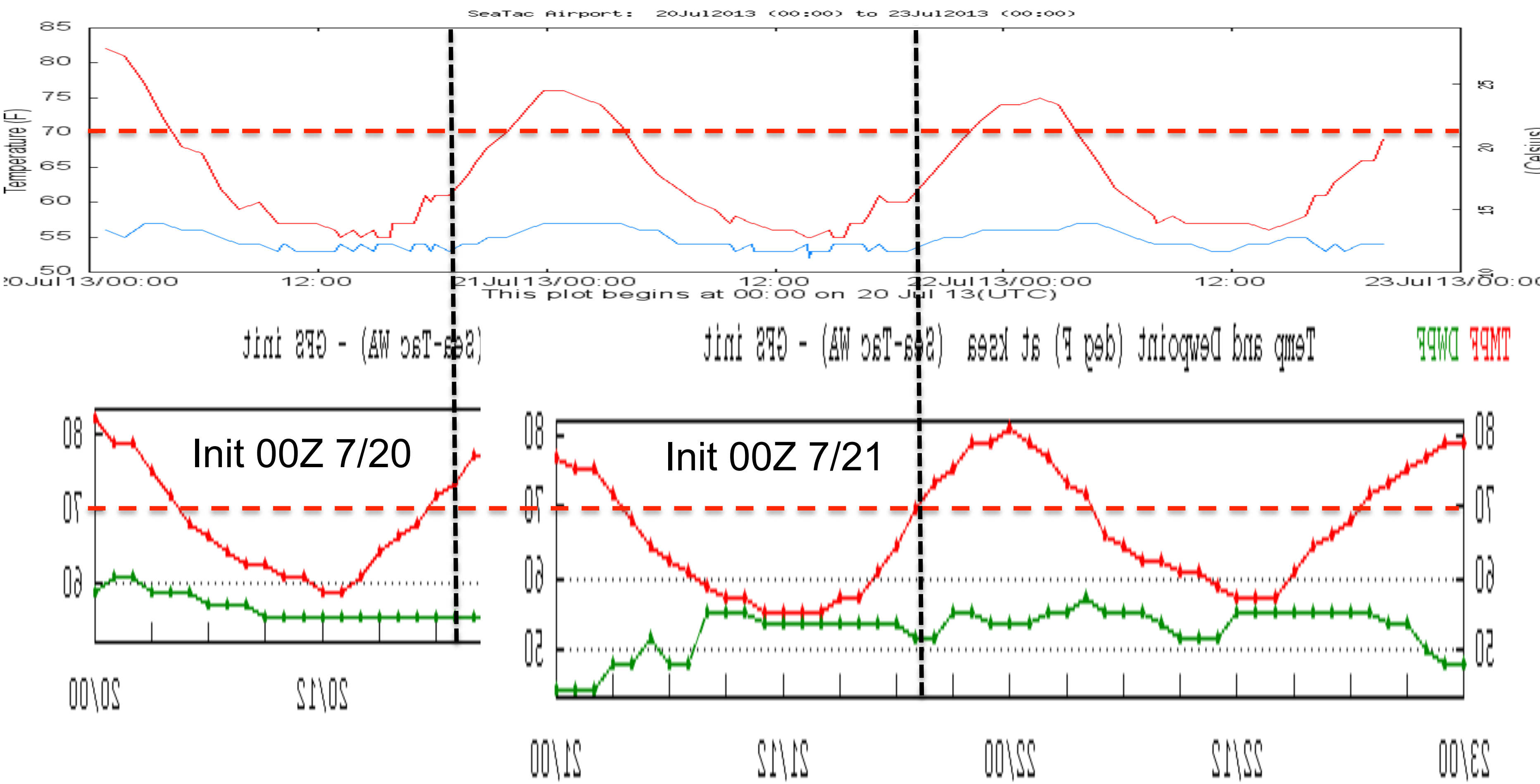
Sc breakup ~ noon

Fog weather – warm aloft, weak onshore flow



How's the Pacific NW 1.3 km WRF doing?

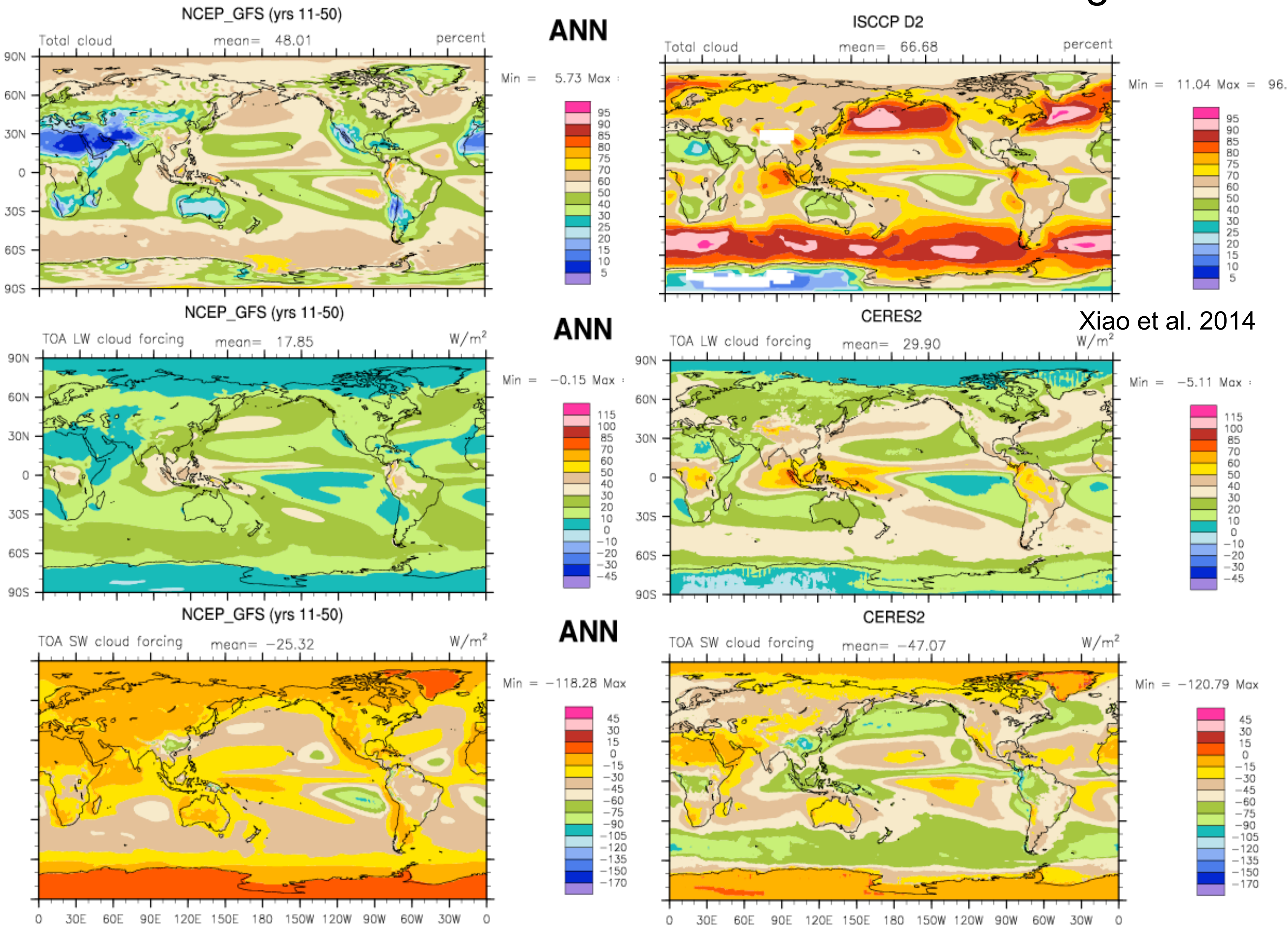
WRF misses the fog and heats up too early at Sea-Tac



Observed noon T on 7/20: 60 F
Forecast noon T: 73 F

Observed noon T on 7/21: 60 F
Forecast noon T: 70 F

Cloud-radiation interaction - a climate model challenge



Xiao et al. 2014

Forecast-mode evaluation of clouds in global models

Goal: Compare clouds globally in weather and climate models and obs when large-scale dynamics haven't yet drifted far from reality ('Transpose-AMIP' for climate model geeks)

Use daily-mean TOA radiation as a diagnostic

- Accurately observed using a combination of polar-orbiting (Aqua/Terra) and geostationary satellites.
- Daily-average maps available within a few months from NASA CERES project.
- Outgoing Longwave (OLR): measure of high cloud

  Reflected shortwave (RSW): measure of total bright cloud
- Together, these can identify key cloud biases and their effect on regional and global radiative fluxes.

Forecast-mode comparison of GFS & GFDL AM clouds

Period: July 2013

GFS: Daily forecasts with 2013 operational (T574L64), pre-op hi-res (T1534L64) versions (O and P)

GFDL: Daily 3-day forecasts from operational GFS analysis using AM3 (2° L48) and AM4*a*2 (pilot version, ~ 1° L48)

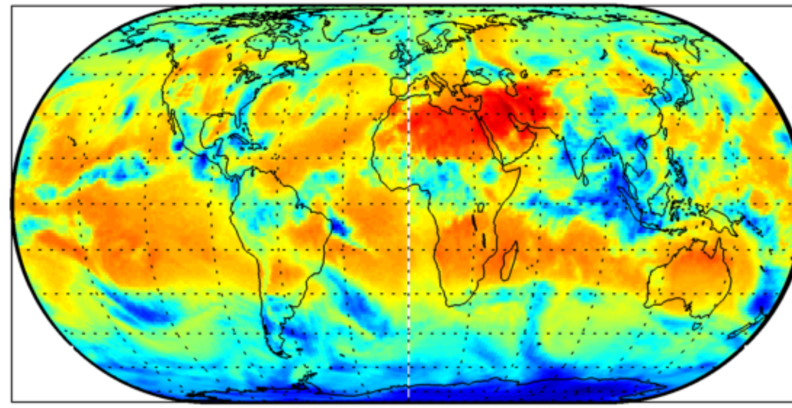
Obs: CERES daily-average estimates of OLR and RSW

Caveat: Possible spinup issues, esp. for GFDL

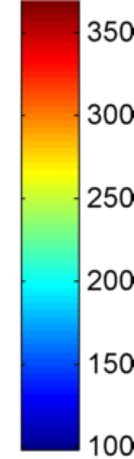
Results generated in Clouds CPT by NCEP and GFDL, analyzed at UW.

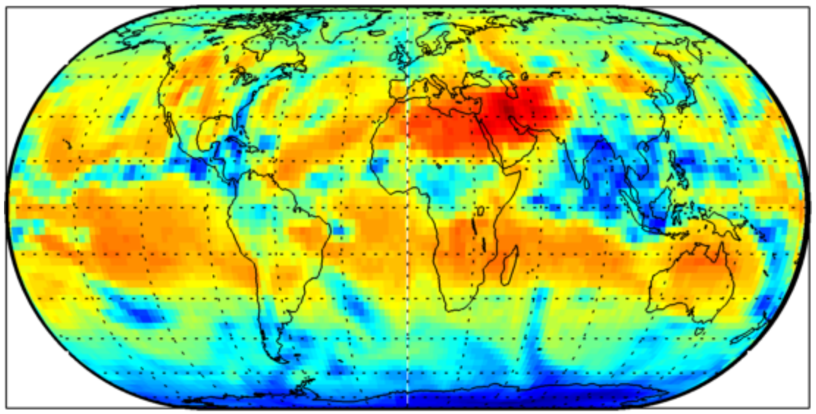
July 2, 2013 OLR AM3 and GFS-O

Both models are on the right planet!

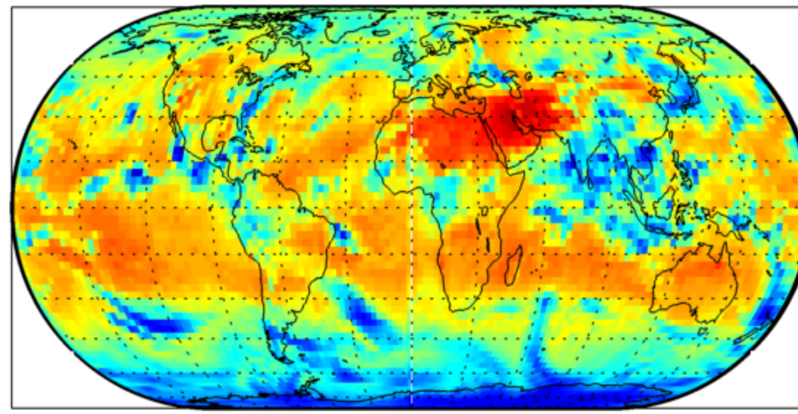


CERES TOA OLR [W/m2]

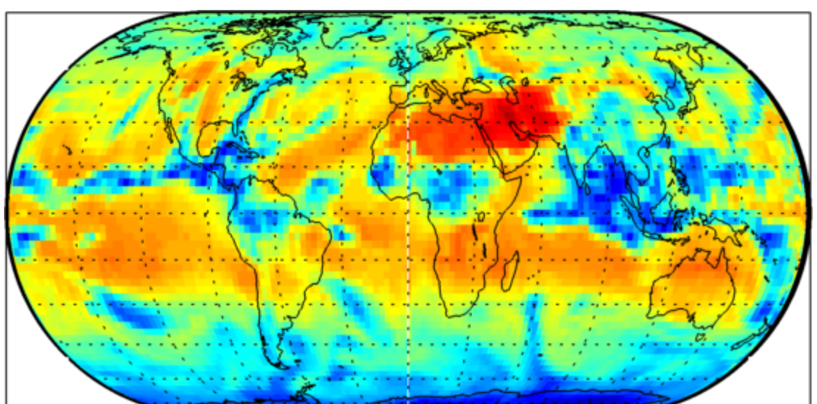




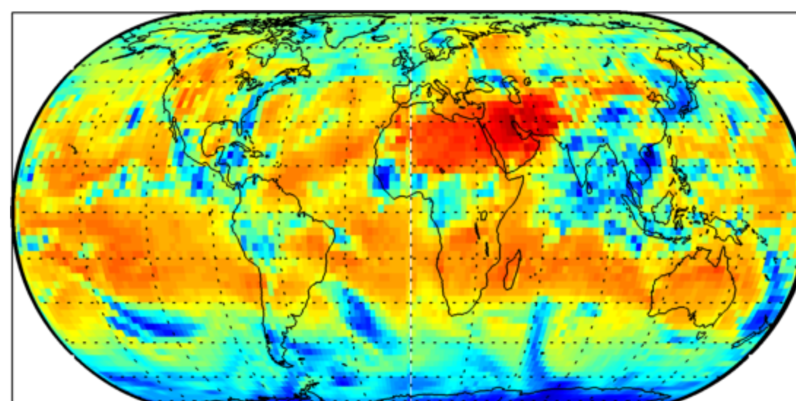
GFDL 0-24 hr forecast [W/m2]



GFS 0-24 hr forecast [W/m2]



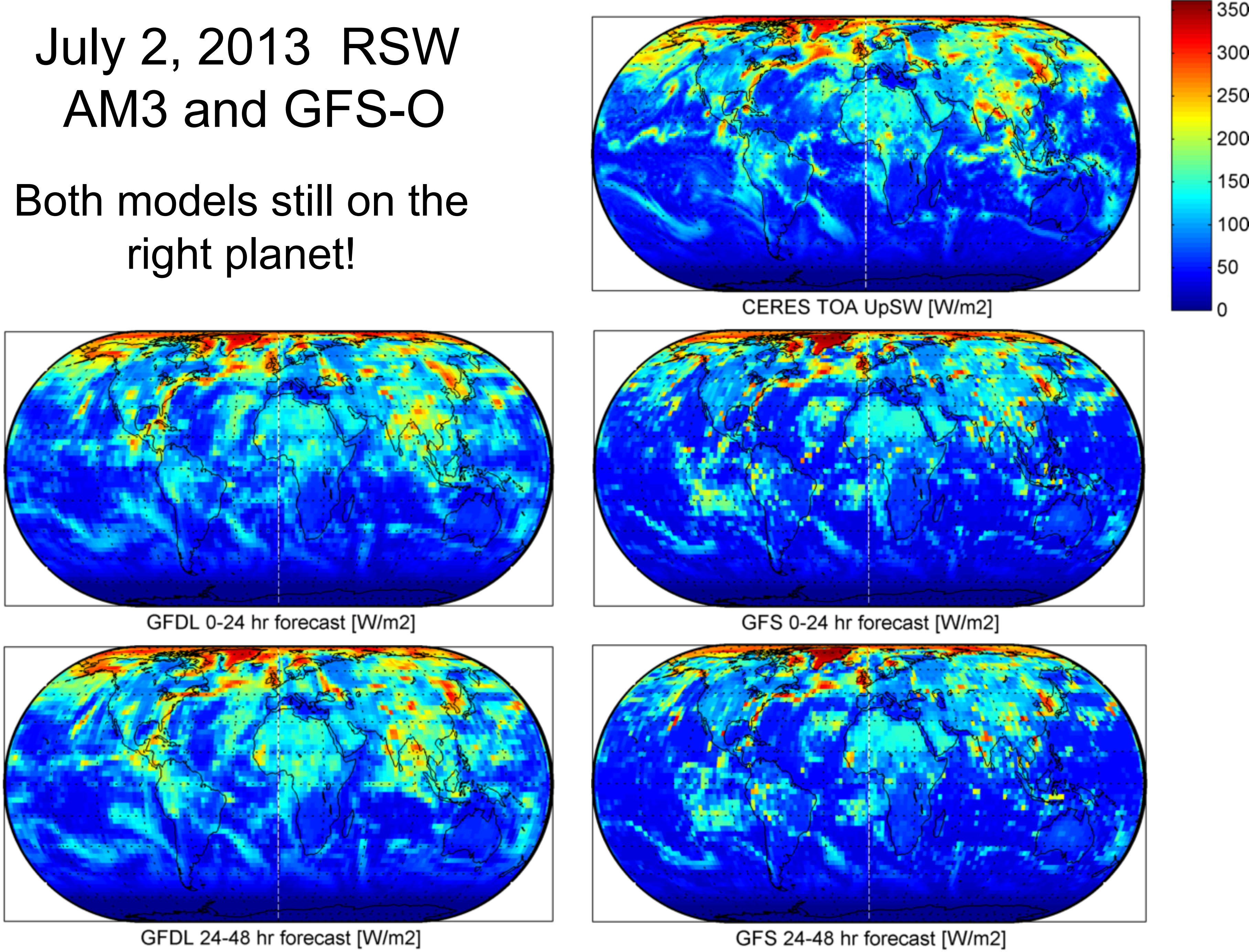
GFDL 24-48 hr forecast [W/m2]



GFS 24-48 hr forecast [W/m2]

July 2, 2013 RSW
AM3 and GFS-O

Both models still on the right planet!



CERES TOA UpSW [W/m2]

GFDL 0-24 hr forecast [W/m2]

GFS 0-24 hr forecast [W/m2]

GFDL 24-48 hr forecast [W/m2]

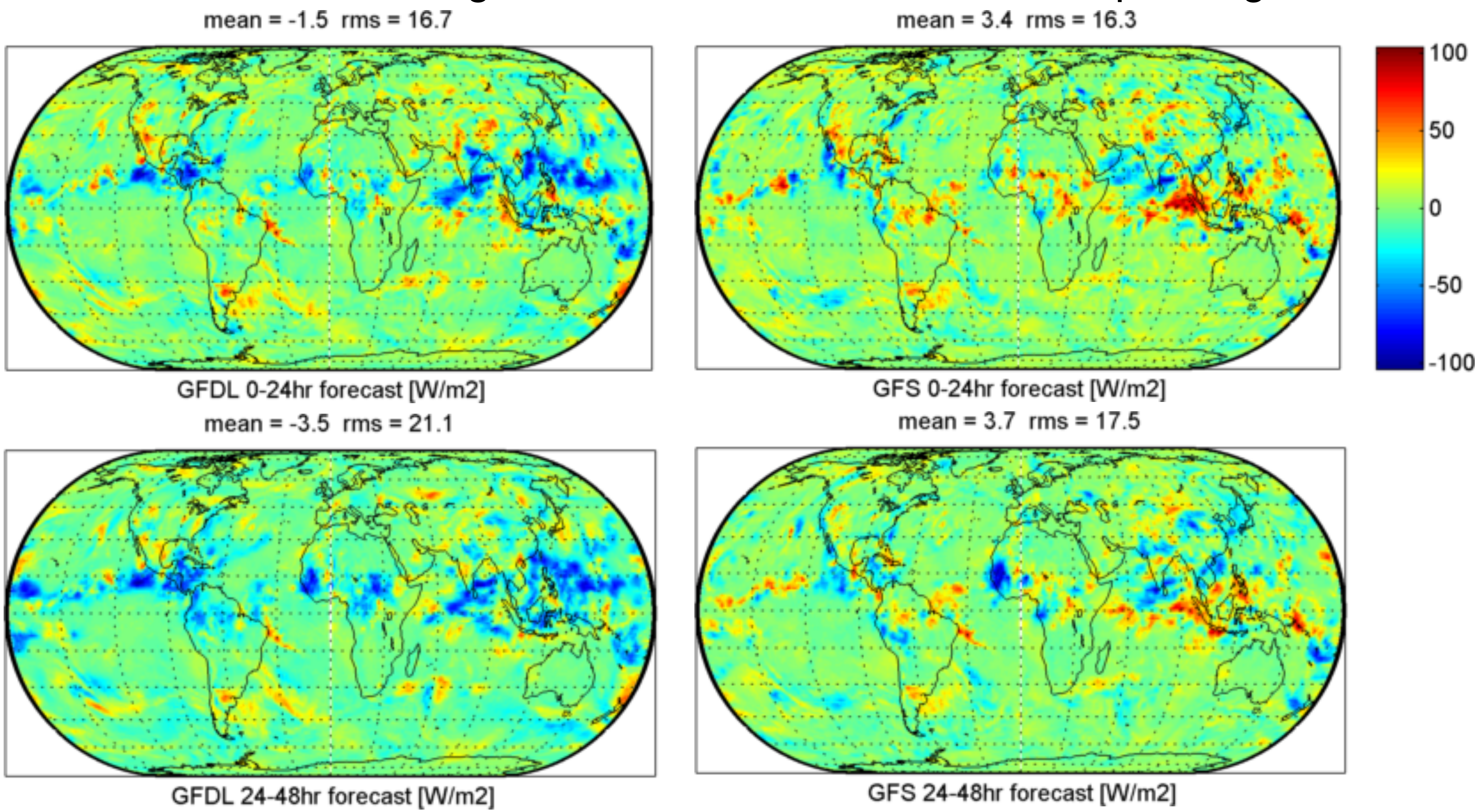
GFS 24-48 hr forecast [W/m2]

July 2, 2013
ΔOLR vs. CERES
AM3 and GFS-O

Models have different regional bias patterns which don't vary with forecast lead

AM3: Too much ITCZ high cloud

GFS: Too little warm pool high cloud

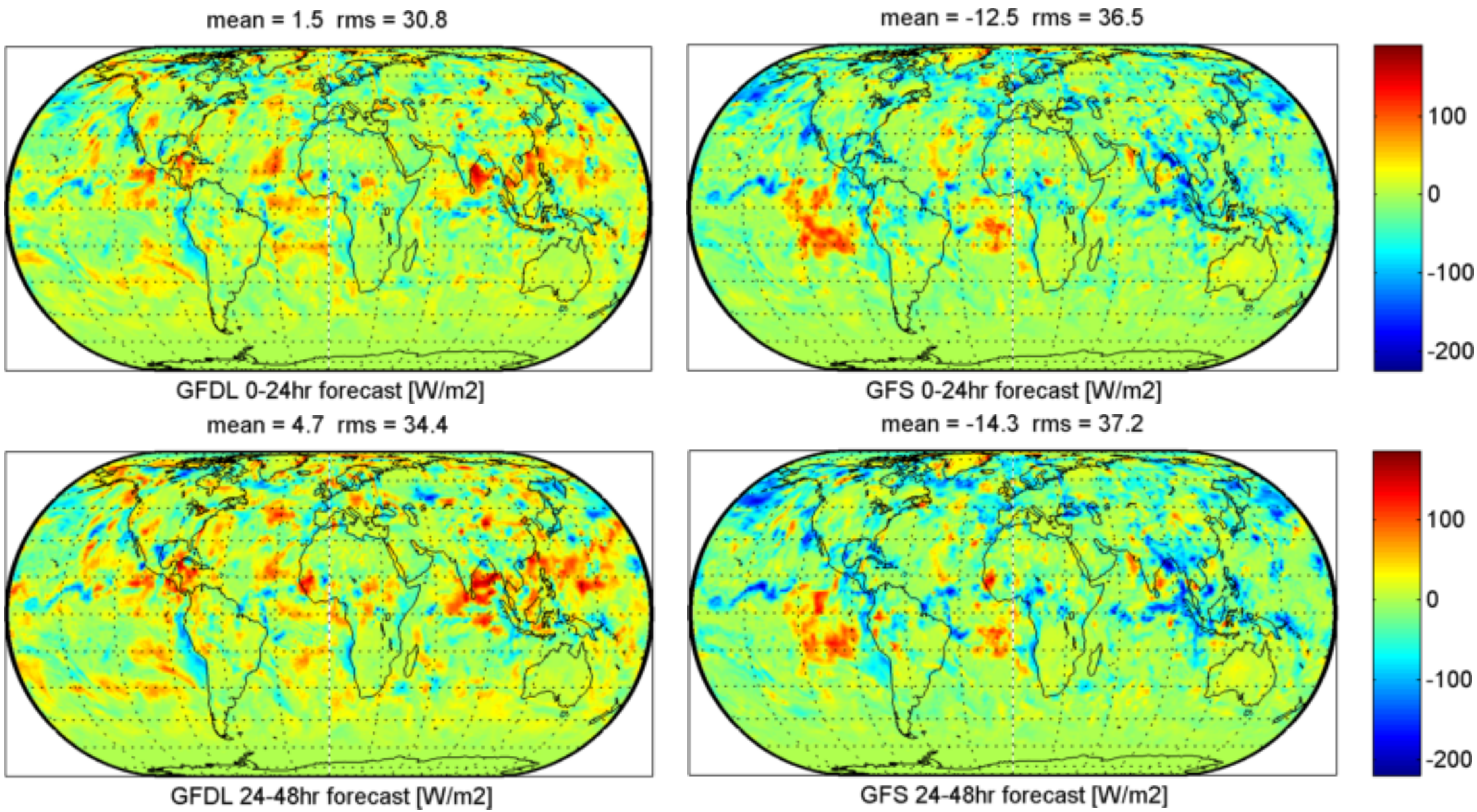


July 2, 2013 ΔRSW vs. CERES AM3 and GFS-O

Models have different regional bias patterns which don't vary with forecast lead

AM3: Too little coastal Sc

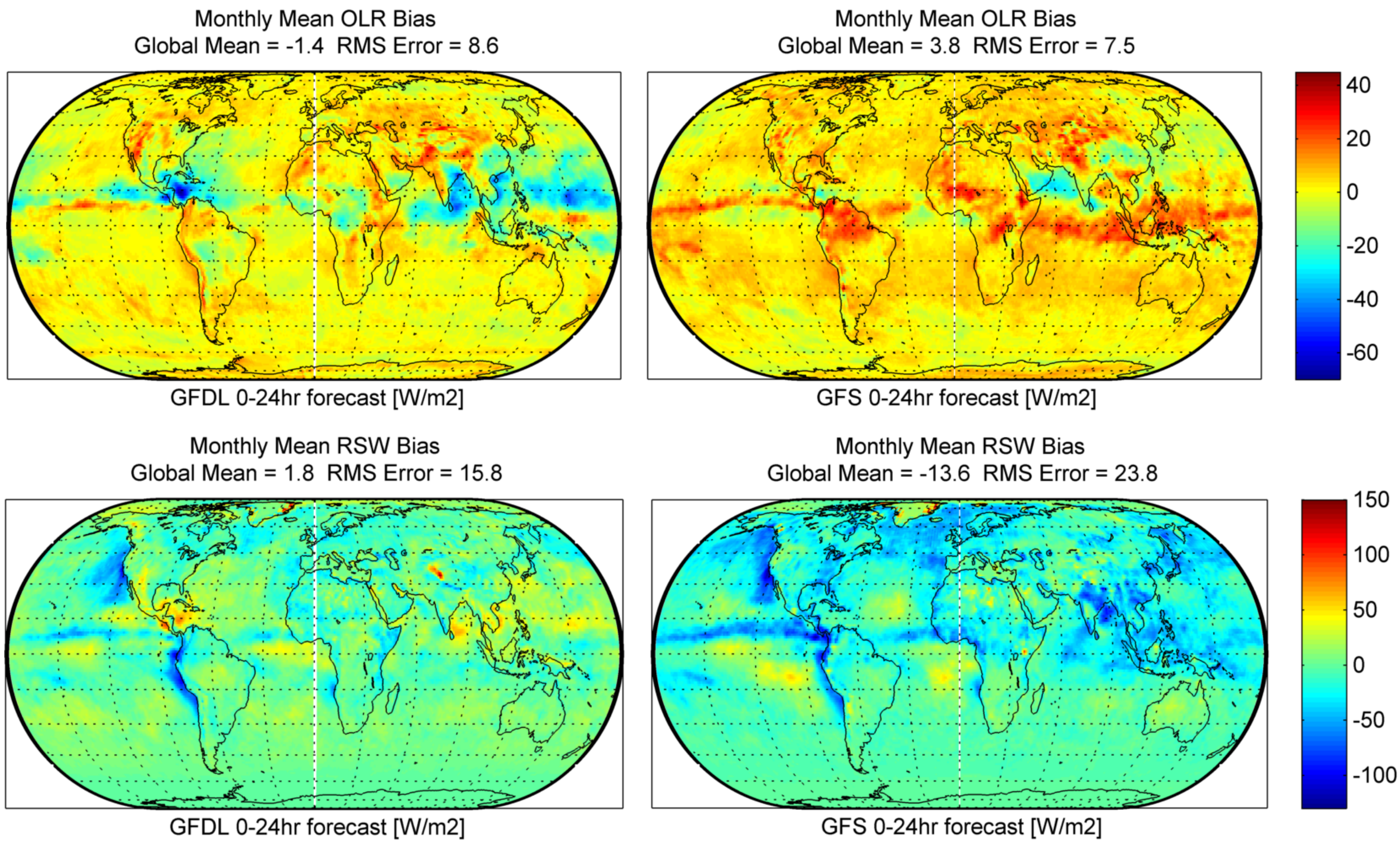
GFS: Too little cloud almost everywhere



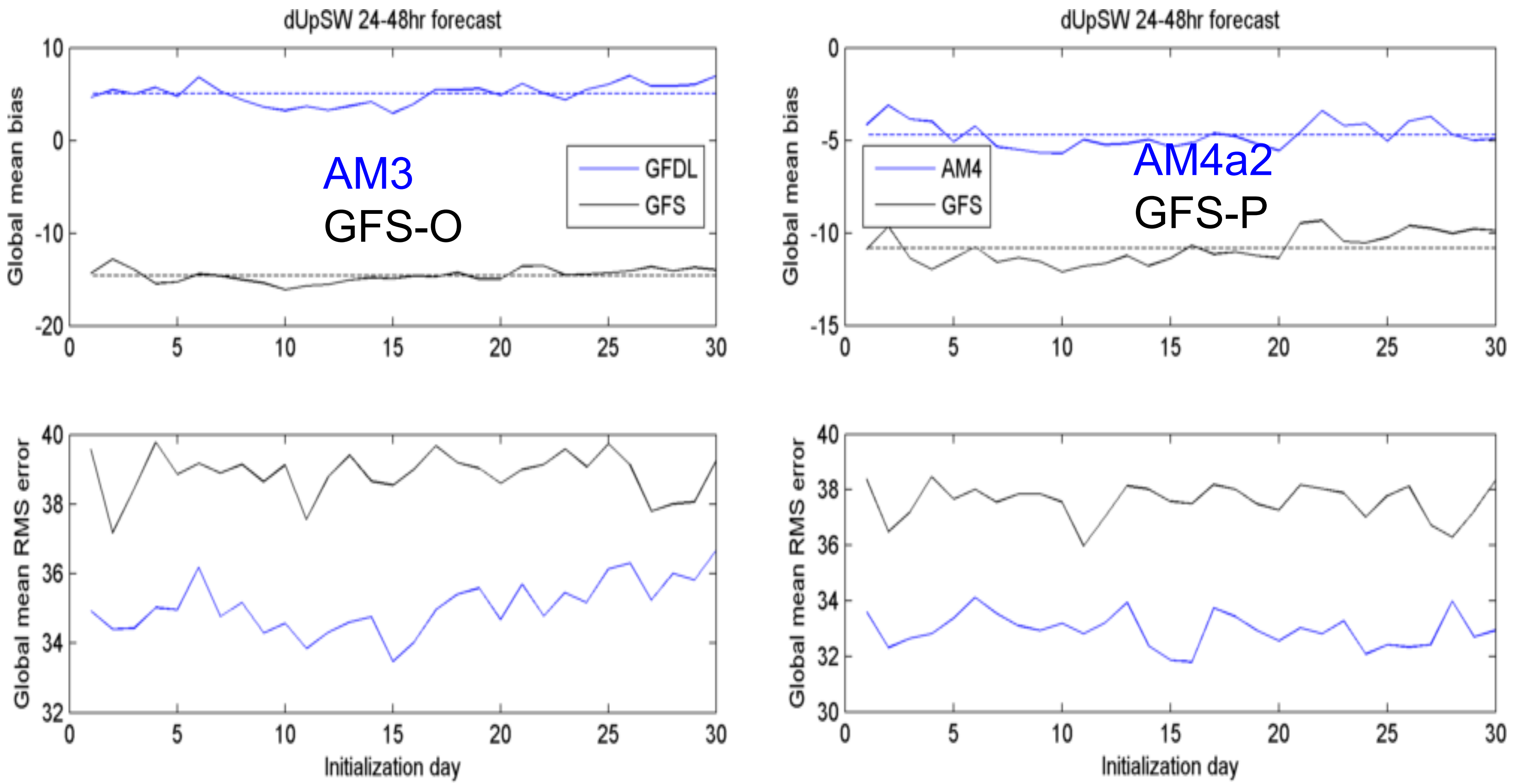
Other days all look rather similar

…summarized with monthly-mean 0-24 hr bias patterns

GFS:10 W m^{-2} global radiation imbalance; climate biases similar



Daily global bias and spatial RMSE: Model version comparisons



- Both prototype versions have slightly reduced RSW RMSE
- Mean biases also slightly reduced in GFS-P vs. GFS-O
- Now comes the hard part: use to target further model improvements!

Implication for cloud-relevant model development

Since clouds respond quickly to local conditions, we should primarily use weather forecasts/hindcasts to test model simulations of clouds. Many years of well-observed weather are a powerful and efficient tool for this.

Climate model ‘tuning’ of cloud-related parameters in models (e. g. critical RH, snow fall speed, autoconversion efficiency) to produce global radiation balance in climate models should be constrained to ‘do no harm’ to hindcast skill in forecasting cloud properties.